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Low-Energy Proton Testing Using Cyclotron Sources

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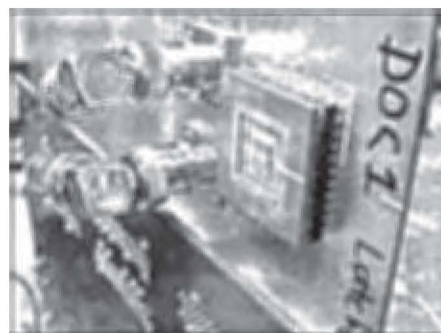
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To be presented by J. A. Pellish at the 2011 Nuclear and Space Radiation Effects Conference (NSREC), Las Vegas, NV USA 29 July 2011 and published on <http://radhome.gsfc.nasa.gov/> and <http://www.nepp.gov/>.

Outline



- Introduction
- Proton facility
 - UC Davis Crocker Nuclear Laboratory (CNL)
 - Beam line monitoring
 - Surface barrier detector
 - Radiochromic film
- Transport simulations
- Missing pieces
 - Angular divergence
 - Beam spot shape
- Conclusions



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UC Davis Crocker Nuclear Laboratory

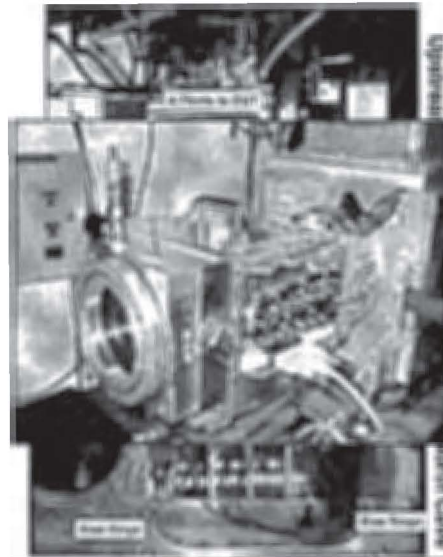
Assuming Setup In-Air (can do vacuum)

- **Upstream-to-downstream progression:**

- Beam diameter on 6.35 μm Ta foil is 0.79 cm
- Defining collimator is 0.95 cm
- Secondary electron emission monitor (SEEM) uses three 6.35 μm Al foils
- User-selected degraders are inserted here (Al or Mylar)
- Kapton exit window and defining collimator
- Air gap is user-selected within experimental parameters
- Can put vacuum chamber here

Ta = tantalum

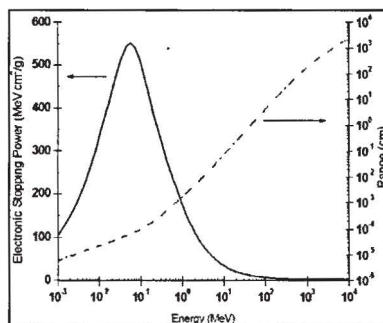
Al = aluminum



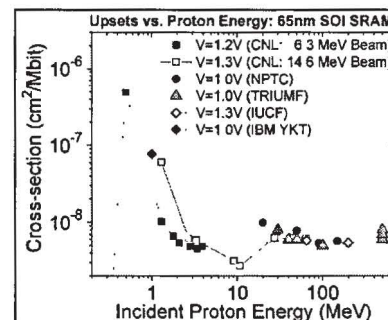
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Low-Energy Proton Testing



NIST PSTAR tool (ICRU Report 49, 1993)



D. F. Heidel et al., TNS, vol. 6, 2008.

- **Cross sections plotted as a function of incident proton energy – inversely proportional to degrader thickness**
 - Several implications/assumptions (just the mean, distribution will change by the time it reaches the sensitive volume, and no flux depletion)
- **Greatest effect in the shortest distance; beam loss at low energy**
- **How do we know the mean energy and standard deviation?**

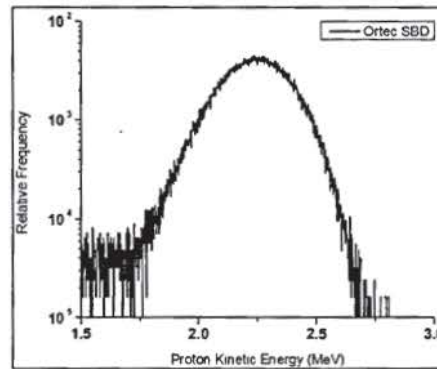
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Beam Line Monitoring



- Use Ortec fully-depleted silicon surface barrier detectors
 - Calibrated with ^{241}Am source
 - Degraded to different energies for multiple cal points
- Provides in-situ information regarding mean and distribution
 - Not a particle counter



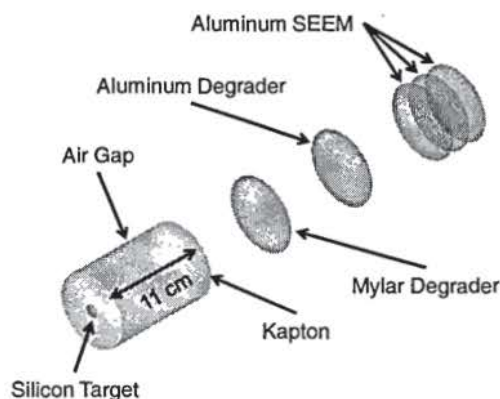
Example SSBD Proton Energy Spectrum

Am = americium
SSBD = silicon surface barrier detector

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MRED 3-D Model of the CNL Beam Line

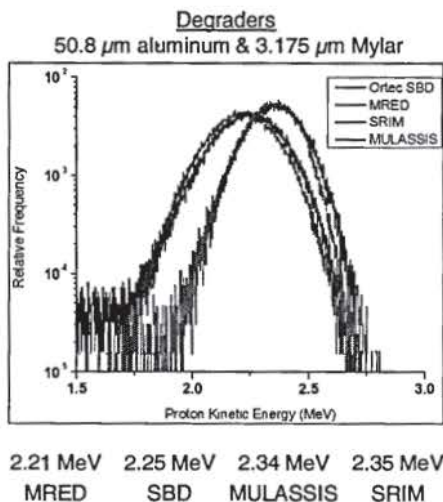


- Realistic setup for an actual run with degraders
 - 6.35 μm Ta scattering foil not shown (~4 m upstream)
 - 3x 6.35 μm Al SEEM foils
 - Al degrader is 50.8 μm
 - Mylar degrader is 3.175 μm
 - 127 μm Kapton exit window
 - 11 cm air gap
 - Silicon target

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MRED, SRIM, and MULASSIS vs. Data

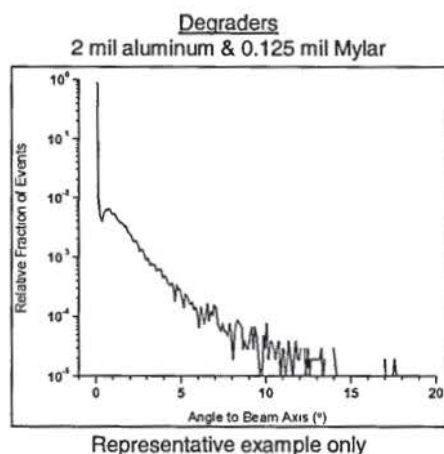


- Beam data comes from a calibrated Ortec B-18-150-300 fully depleted silicon surface barrier detector
- ~120k events for each dataset
- Spacing between beam line elements makes a difference
 - SRIM and MULASSIS are planar stacks
 - Could be additional factors
- Energy distribution appears to be well-described, but what about the spatial distribution?

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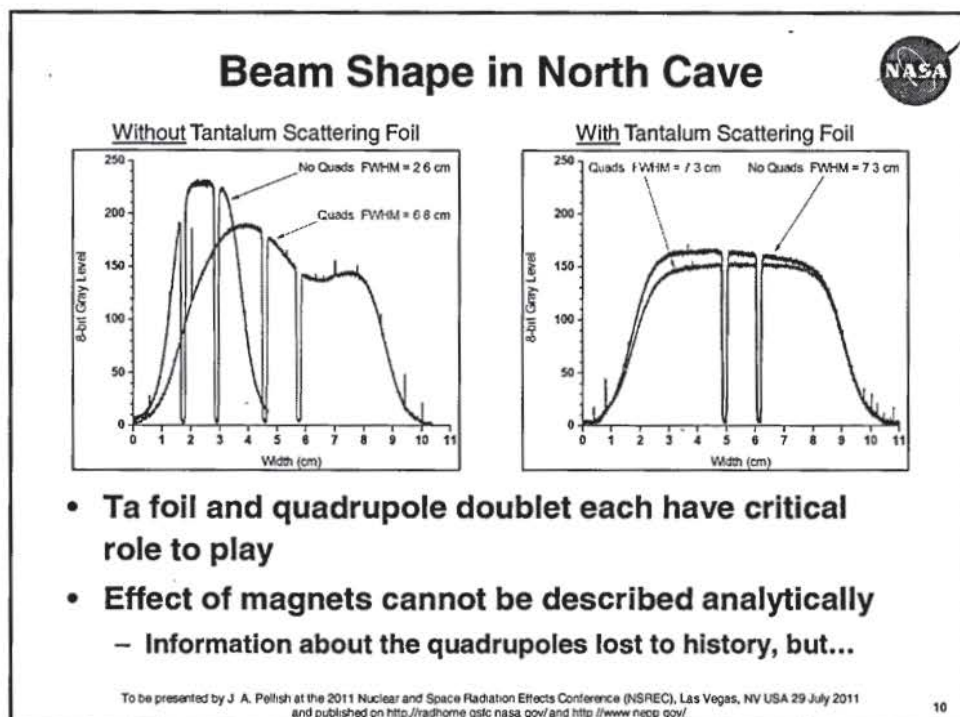
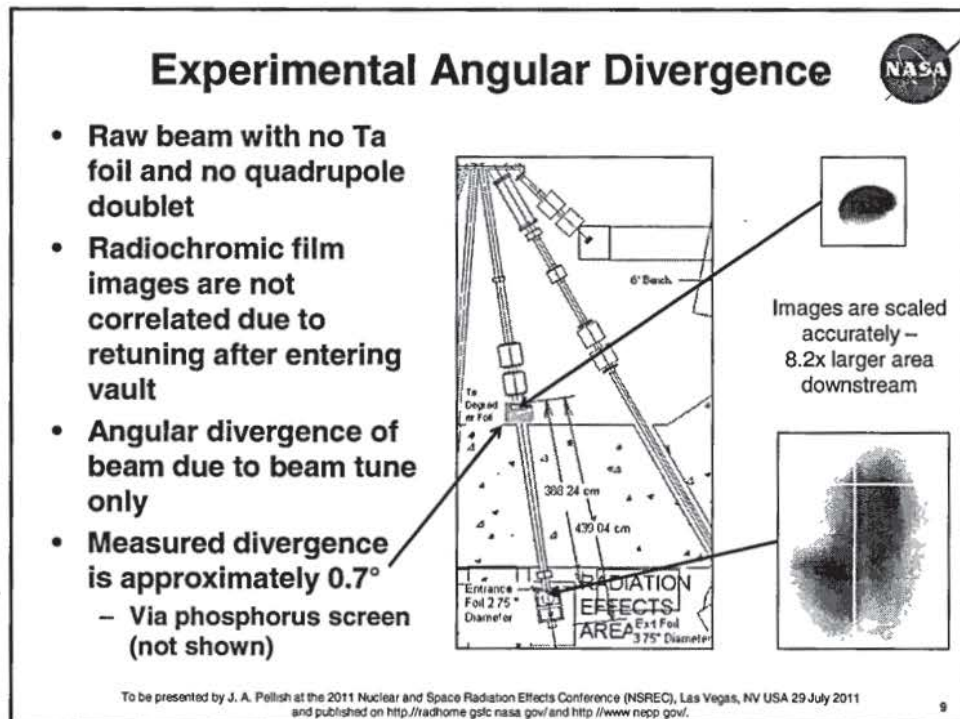
MRED-Simulated Angular Divergence



- Assumes a perfectly parallel beam incident on the Ta foil
 - We know this is false
- Affects energy loss of proton in device under test
- Depends on material spacing along beam line and size of air gap
 - Assumed to be smaller in vacuum (advantage?)

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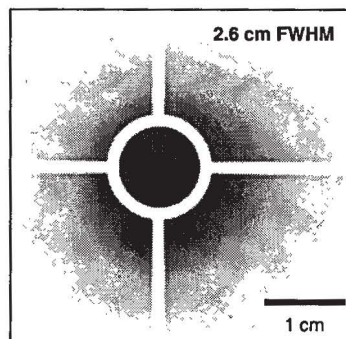
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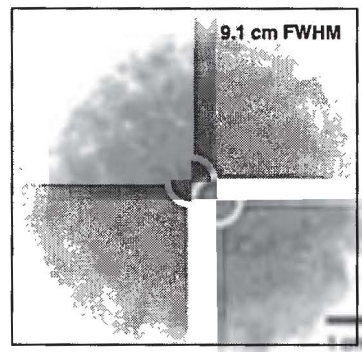
Grayscale Beam Spot in North Cave



No Ta foil + No Quads



Ta foil + Quads



- Pictorial description of quadrupole doublet and Ta foil interactions
- Upshot is that the arrangement works and we can prove it even if we cannot write it down

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Conclusions



- CNL represents ideal (though not only) choice for low-energy proton single-event testing
 - Minimal beam line mass
 - User-controlled degrader setup in vacuum
 - Optional vacuum chamber
- Use beam line monitoring techniques to ensure *post facto* knowledge of the beam characteristics
 - Surface barrier detector
 - Radiochromic film
- Employ radiation transport simulations for *a priori* investigations and Monte Carlo tools, specifically, for advanced rate calculation methodologies
- Need beam energy and momentum characteristics (*i.e.*, beam's emittance) for highest fidelity simulations
 - Energy distribution OK for stopping and range
 - Momentum/angular distribution required for spatial effects

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Questions?

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